Long Range Sediment Tomography

James H. Miller and Gopu R. Potty
University of Rhode Island
Department of Ocean Engineering
Narragansett, RI 02881
Phone (401) 874-6540 fax (401) 874-6837 email miller@uri.edu

Award Number: N00014-98-10058

LONG-TERM GOALS

Our long-term objective is to develop an inversion scheme for the estimation of acoustic properties of sediments in shallow water at long range using broadband explosive sources.

OBJECTIVES

- Design and implement an inversion scheme for range and depth dependent tomographic mapping of sediments in the East China Sea as part of the ASIAEX experiment.
- Validate the inversion with other measurements in the region including gravity cores, chirp sonar, etc.
- Quantify the resolution and accuracy of the inversions.
- Investigate the potential of this method for other shallow water areas as a rapid environmental assessment tool.

APPROACH

A scheme for the estimation of compressional wave speed and attenuation has been developed using broadband explosive sources. Sediment compressional speeds were estimated using hybrid methods based on the modal dispersion behavior of broadband acoustic propagation. In this hybrid scheme, we have used Genetic Algorithm (GA) as the main search tool. Local optimization tools were used to fine-tune the inversion. This scheme is discussed in detail by Potty, Miller, Lynch and Smith[1]. Attenuation values were estimated by another inversion scheme based on modal amplitude ratios. In addition to sediment properties other parameters such as bathymetry, source-receiver range, source depth, receiver depth and source level were also estimated in this inversion scheme. Source receiver range was also estimated using the travel time differences of different modes and the calculated group speed values. We have applied our inversion scheme to the data from the Shelf Break Primer Experiment conducted in the summer of 1996. The results of this inversion were successfully compared with core data from Atlantic Margin Coring (AMCOR) project and gravity cores.

Using the experience gained from the PRIMER experiment, we planned and conducted a similar study at the ASIAEX site in the summer of 2001. Our major effort concentrated on data acquisition and inversions in the East China Sea. One interesting feature of the sediment sound speed pattern is the presence of a ‘sediment front’ separating a low speed region to the northeast from a high-speed region in the southwest. The presence of this sediment front was also reported in literature by Niino and

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Long Range Sediment Tomography**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Rhode Island,,Department of Ocean Engineering,,Narragansett,,RI, 02881**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Our long-term objective is to develop an inversion scheme for the estimation of acoustic properties of sediments in shallow water at long range using broadband explosive sources.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Emery[2]. To gather more sediment information, a small number of gravity cores were taken from the experimental site in 2000. The right panel in Figure 1 shows the contour of the compressional wave speeds in the top layer of the sediments. These values are the vertically averaged sound speeds from the cores taken at 15 locations in the area. The average sediment compressional speed in the area is of the order of 1600 m/s. Variations as high as 60 m/s can be seen the figure. Note the contrast in the surficial sound speed on either side of the ‘sediment front’. We feel that this distribution of sediments is an ideal environment to test our inversion scheme. We proposed a circular deployment of SUS charges around the receiving array, with shots on either side of the ‘sediment front’. The radius of this circle is 30 km. In addition to the circular run, we also proposed radial runs as shown in Figure 1.

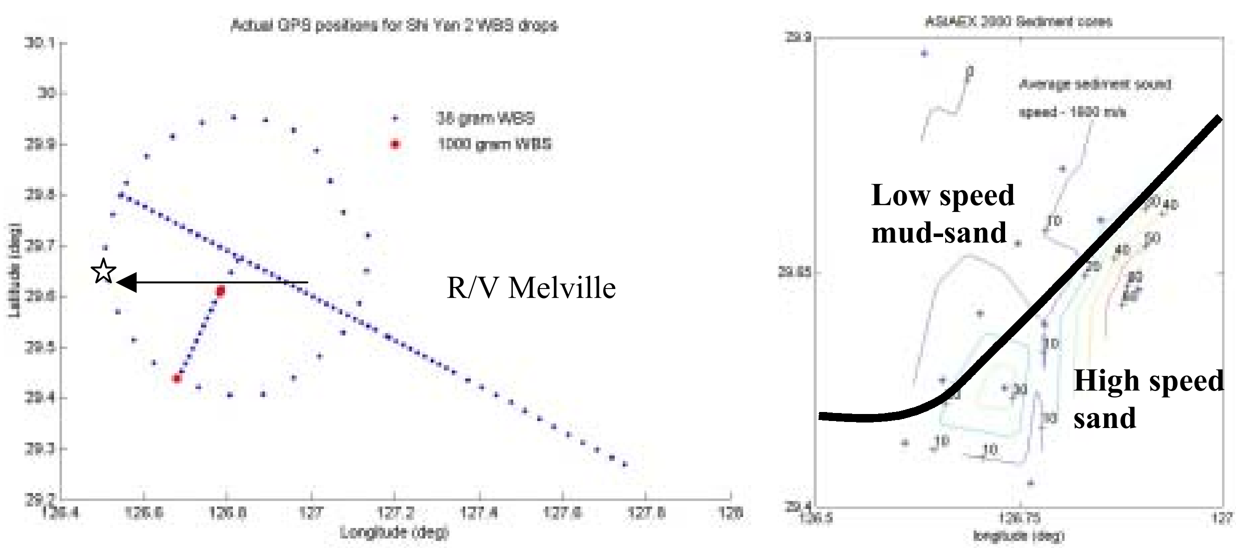

Figure 1. Locations of the SUS charge drops in the East China Sea is shown in the left panel. Right panel shows the contour of the compressional wave speeds in the top

WORK COMPLETED

The design and implementation of the experiment has been successfully completed in May-June 2001. The APL/UW vertical line array, consisting of 16 hydrophones and the URI data acquisition system were used to acquire the data. The top and bottom hydrophones in the VLA were at depths 34.6 m and 94.6 m respectively. The VLA was deployed from R/V Melville and the explosives were deployed from the Chinese research vessel Shi Yan 2. Over 200 shots of weights 38 g and 1000 g were deployed for reverberation and propagation studies. The locations of these shots were recorded using a handheld GPS. The recorded locations of the SUS charges are shown in Figure 1. These shots were set to explode at a depth of 50 m but we expect some variation in the source depths.

Acoustic arrivals on the vertical line array from all the shots have been identified and extracted. The time-frequency analysis of these signals using wavelet-based method has been completed. The dispersion of the modal arrivals can be observed from these time-frequency scalograms. The arrival times corresponding to various modes form the basis for our inversion scheme. We are also exploring

various methods to efficiently and accurately extract the modal arrival times from the time-frequency diagrams using image processing techniques.

Another short cruise aboard the Taiwanese research vessel OR2 with Korean and URI scientists is planned in August, 2001. Cores will be taken at selected locations during this cruise to augment the sediment property information. This core data will provide sediment compressional speeds and attenuation for comparison and validation of the inversions.

RESULTS

Figure 2 shows the early results from the study. The acoustic signals received at the Yellow Sea array from two explosive charges at 30 km and their time-frequency diagrams are shown in this figure. These signals were received at a hydrophone depth of 78.6 m. Both Shot 'A' and Shot 'B' were 38 gm explosive charges at 50 m depth deployed at 30 km from the receive array. Shot 'A' was on the NW side of the experimental area where the sediment is a soft mud-sand type. Shot 'B' was on the SE side, were high speed sandy sediments were present. This figure presents the comparison of dispersion of these signals over the same range. Water depth varies from 105 m at the NW corner to about 120 m at the SE corner. The initial arrival is stronger in Shot 'A' whereas the higher modes are more prominent in Shot 'B'. Up to nine modes can be identified in the dispersion diagram for Shot 'B'. Note that the actual depth at which the shots may be different for the two charges. The arrival times shown are arbitrary.

IMPACT/APPLICATIONS

This inversion scheme using explosive sources is suitable for rapid estimation of acoustic properties of sediments in shallow water. This method is cost effective as a single sonobuoy and air-deployed explosives can provide the data. Using multiple sources and receivers sediment properties would allow an area to be mapped.

TRANSITIONS

The sediment parameters obtained by this inversion can be used for the forward modeling efforts at East China Sea. Our technique is suitable for forward force deployment when rapid assessment of environmental characteristics is necessary. In addition to naval air ASW applications using sonobuoys and SUS charges, this technique would be compatible with Navy special operations involving autonomous vehicles. In that scenario, the vehicle could drop a small timed charge and receive the acoustic signals at a distance. This would allow the sediment properties to be estimated in the area.

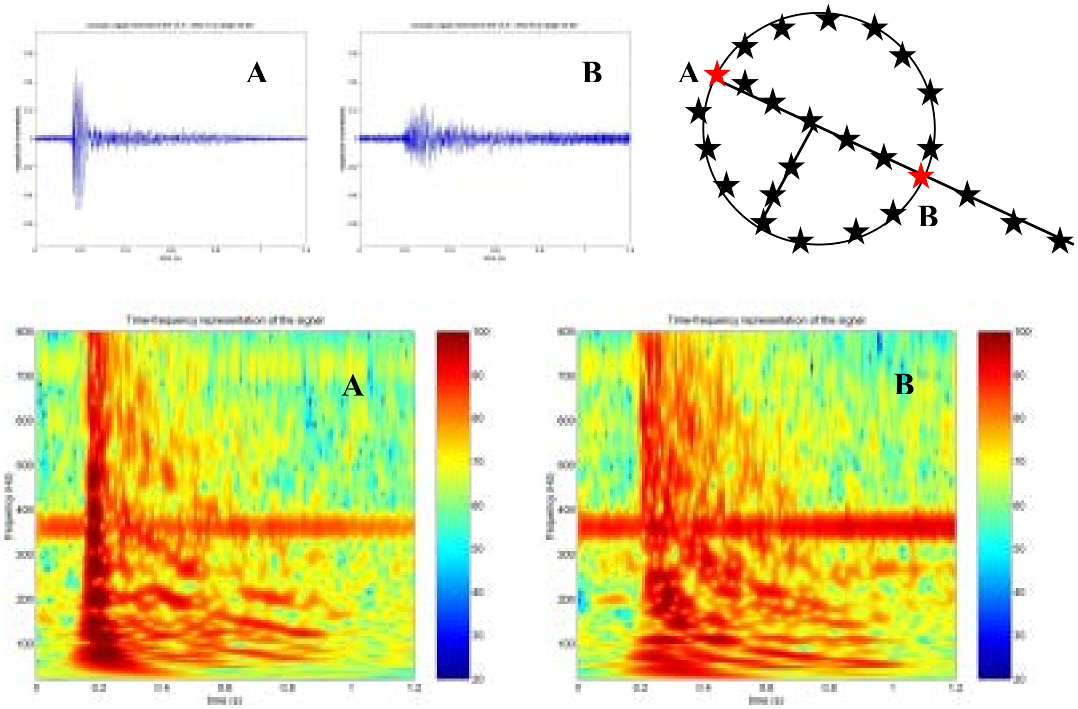

Figure 2: Acoustic Signals received at the APL-UW 'Yellow Sea' array. The data was recorded using the URI data acquisition system. The top panels show the time series from two WBS charges 'A' and 'B' (indicated in the Figure) and the bottom panels show the time-frequency diagrams. The time-frequency analysis was carried out using a wavelet based approach.

REFERENCES

1. G. R. Potty, J. H. Miller, J. F. Lynch and K. B. Smith, "Tomographic inversion for sediment parameters in shallow water," J. Acoust. Am. 108 (3), 973-986, (2000).

2. Niino. H and Emery. K.O, "Sediments of shallow portions of East China Sea and South China Sea," Geological Society of America Bulletin, vol. 72, 731-762, (1961).

REFEREED PUBLICATIONS

1. G. R. Potty, J. H. Miller, "Non-linear optimization techniques for geoacoustic tomography," in *Inverse Problems in Underwater Acoustics*, edited by Taroudakis. M and Makrakis. G, Springer Verlag, New York, (1999)

OTHER PUBLICATIONS

1. G. R. Potty and J. H. Miller, "Sediment tomography in the East China Sea," J. Acoust. Soc. Am., 108, 2536 (2000).